One Health 20 (2025) 101019

Contents lists available at ScienceDirect

One Health

journal homepage: www.elsevier.com/locate/onehlt

Teaching inequity in vector-borne diseases management through a socioscientific issue framework

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ARTICLE INFO

Keywords:
Vector-borne disease
One health education
Lesson plan
Equity
Socioscientific issues
Place-based education

ABSTRACT

The distribution and management of vector-borne diseases (VBD) are affected by a social and cultural environment, including forms of systemic oppression such as racism and classism. University classes that cover these diseases usually focus on teaching biological concepts while skimming over other social, economic, and cultural factors that influence them. With no current lesson plan widely available to implement, we present a lesson plan intended to be delivered at the end of courses related to disease ecology to emphasize inequity issues that impact VBD management while also serving as a capstone for the biological content taught in the class. The lesson is based on the demographic and disease risk data from local contexts to provide effective place-based and socioscientific issues instruction. The lesson is designed as a role-playing simulation where groups of students are given separate disease outbreaks to combat with specific budgets. Therefore, each group has unequal resources to manage the disease depending on their specific local context. The simulation is followed by a discussion about equity in disease management. To make this activity broadly applicable, the lesson plan has been written in four languages (English, Portuguese, Spanish, and Mandarin) according to a diversity of corresponding locations (Texas-USA, Brazil, Spain, and China), which are included in the supplementary materials. Incorporating this lesson into curricula across multiple disciplines is an important step for developing future entomologists, parasitologists, epidemiologists, and other One Health professionals to address disparities in VBD control and help drive the field forward equitably.

1. Introduction

Vector-borne diseases (VBD), such as malaria, Lyme disease, and West Nile Encephalitis are caused by parasites, bacteria, or viruses transmitted via an invertebrate vector (e.g., mosquitoes, ticks). Over half of the world's current population is at risk of being infected with a VBD, and as much as one-sixth are currently suffering from a VBD-caused illness or disability [1]. Many of these diseases are considered neglected tropical diseases that often disproportionately affect communities living in poverty [1,2]. This is due to several complex socio-cultural, ecological, economic, and political-institutional factors [3] that hampers the availability of resources for vector control. However, this lack of resources may not necessarily be a result of a lack of willingness to pay for vector control efforts among the public. For instance, in Hidalgo County, Texas, United States of America (USA), individuals were willing to pay, on average, $51.87 per year for mosquito control although current funding through taxes and grants is $0.05 per person per year [4]. By contrast, in Harris County, Texas, residents are willing to pay approximately the same amount for control efforts, and $2.00 is allocated per person per year for mosquito control [4]. However, the risk

Abbreviations: CDC, Center for Disease Control; NSF, National Science Foundation; PBE, Place-based education; SSI, Socioscientific issue; STEM, Science Technology Engineering Mathematics; VBD, Vector-borne disease.

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https://doi.org/10.1016/j.onehlt.2025.101019
Received 28 August 2024; Received in revised form 13 March 2025; Accepted 24 March 2025
Available online 25 March 2025

of VBD in these counties is markedly different. In early 2017, the Texas Department of State Health Services listed Hidalgo County as a high-risk county for Zika virus, and by the end of the year Hidalgo had the highest local mosquito-borne acquisition case count for 2017 in the US [5]. However, none of the Zika cases in Harris County were confirmed to be locally acquired in the same period [6]. The major demographic differences between these two counties are population density, race, and average household income (Table 1), all of which have been factors associated with vector-borne disease risk [7–10]. Alternatively, publicly funded vector control programs among regions in USA where tick-borne diseases are a constant risk do not take actions to reduce tick populations on public lands and additionally are not willing to suppress tick populations on privately owned land [11–13]. This leaves the brunt of the responsibility to the individual to initiate VBD prevention methods, which would be difficult for many due to financial security or knowledge of risk. Racism and other oppressive systems and their roles in VDB management have been consistently highlighted in the literature [10,12–14].

Social and economic inequalities are rarely addressed in university classes that teach VBD as such courses traditionally focus on the key biological factors (e.g., pathogen, host, vector, and environment) that affect VBD dynamics [15]). Recent studies support the notion that society and social factors influence and interact with VBD [12,16], but this accepted reality has not always been translated to the classroom environment. As we train the next generation of vector biologists, infectious disease doctors, epidemiologists, veterinarians, and public health scientists who will be managing these issues and treating patients, it is important to educate them on the social and political contexts that affect the prevention and mitigation of VBDs. Moreover, though a variety of disease outbreak games exist [17,18], to our knowledge there are none that address resource inequity or that draw from place-based education (PBE) models under a socioscientific issues (SSI) framework (see explanations for these concepts below). Considering and addressing social, economic, and other inequalities is essential to implement broadly targeted health initiatives such as the One Health approach [19], which is based on multi- and interdisciplinary collaborations to improve the health of people, animals, and the environment [20].

In this article, we present a place-based, SSI lesson featuring a role-playing game about VBD aimed at increasing awareness about these inequities and fostering the development of compassionate future health professionals. Although the lesson we present is located within Texas, USA (Supplementary Material: Appendix A), we encourage educators to adapt this lesson to their own regions to make this activity locally relevant to stay within the realm of place-based education. We have included similar lesson plans for Brazil (Supplementary Material: Appendix B), China (Supplementary Material: Appendix C), and Spain (Supplementary: Appendix D) in their local languages. Although there are intra- and inter-region disparities within countries in terms of funding for VBD control, transparency in VBD cases, surveillance of VBD, and accessibility to these data, educators adapting the lesson plan should ensure the activity remains relevant and impactful for local trainees. This can be achieved, for example, by collecting information from local news, textbooks, and peer-reviewed literature with data from the focal areas if government does not easily provide such information. Lastly, this lesson is designed to be given in entomology, parasitology, public health, or zoonotic disease classes at the undergraduate level, though we encourage other entities and courses to use this lesson to their advantage.

2. Lesson background

This lesson utilizes research-based theories of teaching and learning to meaningfully engage students with VBD management to bolster their science content understanding and foster empathy towards stakeholders

Table 1
Demographic information from the United States Census Bureau and vector-borne disease risk data from Texas State Health Department for the five Texas counties chosen for a lesson plan example.

					Locally acquired vector-borne disease cases		
County	Population density (per sq mile in 2020)	Race & Hispanic origin in 2022	Median household income in 2022 ($)	Education level in 2022	Flea-borne typhus cases from 2008 to 2019	Spotted fever rickettsioses cases from 2014 to 2020	West Nile Virus cases from 2013 to 2023
Hidalgo	554.3	White 96.8 % Hispanic 92.5 % Black 1.0 % Asian 1.1 % American Indian 0.6 %	44,666	High school graduate or higher 67.3 % Bachelor's degree of higher 19.5 %	1053	28	17
Nueces	420.9	White 90.6 % Hispanic 65.4 % Black 4.3 % Asian 2.3 % American Indian 0.9 %	59,477	High school graduate or higher 84.1 % Bachelor's degree of higher 21.9 %	667	60	16
Harris	2771.7	White 68.5 % Hispanic 44.6 % Black 20.6 % Asian 7.5 % American Indian 1.2 %	65,788	High school graduate or higher 81.9 % Bachelor's degree of higher 32.5 %	252	18	282
Dallas	2993.6	White 65.5 % Hispanic 41.5 % Black 23.9 % Asian 7.2 % American Indian 1.1 %	65,011	High school graduate or higher 80.7 % Bachelor's degree of higher 33.0 %	50	7	224
Travis	1297.9	White 78.0 % Hispanic 33.0 % Black 9.4 % Asian 8.4 % American Indian 1.2 %	85,043	High school graduate or higher 90.6 % Bachelor's degree of higher 52.7 %	306	0	24

impacted by VBDs. Aligning with Constructivist Learning Theory [21], this lesson follows a 5-E lesson structure [22–24] that prompts students to reconstruct and build upon their prior knowledge of VBD by applying it in a new context. Students also must co-construct their knowledge of VBD management by collaborating to develop disease management plans. Additionally, this lesson forefronts Situated Learning Theory and Self-Determination Theory by having students engage in a real-world, authentic context that draws on their intrinsic motivation to help others and their community [25,26]. Socioscientific Issues and place-based education frameworks provide further empirical support for this lesson design.

3. Socioscientific issues framework

Socioscientific issues (e.g. climate change and genetically modified organisms) are complex, value-laden science issues that require the consideration of social, ethical, and economic facets [27,28]. Equitably resolving SSI requires STEM professionals (careers related to science, technology, engineering, and mathematics) who can think critically and take the empathetic perspective of others when making decisions. This lesson draws from scholarship on effective SSI instruction to prepare college students to expertly engage with societal issues that require scientific and moral considerations.

Scholarly recommendations for teaching SSI include utilizing culturally relevant, ill-structured science issues with economic and social ramifications that require students to engage in evidence-based reasoning and argumentation [29]. There are many benefits to this type of instruction, including the development of communication skills, the ability to distinguish scientific issues from nonscience, and the discerning of what data and evidence are reliable [27]. Moreover, SSI instruction supports students developing an interest in science, an understanding of scientific methodology, and improved reasoning skills [28]. SSI is also linked to character building [27] and has been shown to make students more sensitive to moral and ethical aspects of scientific discovery in addition to increasing compassion to a diverse set of people [30].

VBD management is a complex, value-laden issue that raises several social, economic, and ethical issues. With this lesson plan, students will engage in discussions that require them to consider both scientific and equity concerns within VBD management in a local context (Supplementary Material: Appendix A-D). We aim to guide students in the learning process about moral and ethical issues related to science and for them to gain a greater level of scientific literacy and compassion.

4. Place-based education

At the root of PBE is the idea that science learning should connect to the lived, and thereby local, experience of the students [31]. PBE aims to move education away from only gaining knowledge by reading books or listening to lectures, but to base learning on experiences in the world around us [32]. Characteristics of PBE include focusing on a local issue, allowing students to be creators of knowledge, and linking the community and lived experience of the students to the classroom [32]. Prior empirical scholarship demonstrates that utilizing personally relevant contexts to teach science bolsters students' sense of agency [33] and leads to stronger community ties and a deeper appreciation for nature [34]. Recent scholarship has called for education that foregrounds peoples' engagement with local disease ecology issues including proposing and implementing solutions for their community [35]. In the same study, the authors clarify that science content knowledge and research alone are not sufficient to improve people's health and well-being [35]. When working to solve VBD issues and improve health, people must consider a variety of factors, including ethics, cultural values, and economics, to make informed decisions. Given that VBD are widespread, some students may have personal experience that have influenced them and that they bring to the classroom, making PBE a particularly relevant mode to learn about these topics.

The lesson plan we present here follows a place-based approach built around Texas, USA, as we initially built this lesson for groups at Texas A&M University. We also included three supplemental models for different locations in their local languages to make adapting the lesson to their own geographical contexts easier. Our intention is to provide some example lessons that can be used in their local places or be adapted to conserve the benefits of place-based education. Since our location is a Texas University and most students are from across the state of Texas, we chose the whole state as our local context. When adapting this lesson plan, it is important to choose a regional scale that not only follows PBE principles but encompasses the true disparities that exist and the VBD that are circulating in that locale. For instance, there are 254 counties in Texas, yet there are only 14 county-level and 1 city-level mosquito control and surveillance districts of the Texas Department of State Health Services. However, the distribution of VBD and risk does not reflect the distribution of these control and surveillance districts (Table 1) [36]. Furthermore, when adapting this lesson plan to a local region, it is imperative to base the prompts off a spectrum of true VBD risk in that area and match biologically true aspects of a VBD (Table 1; Supplementary Materials: Appendix A-D). Although, the budgets and VBD experts within each prompt should be entirely fictional but should mirror a spectrum of resources to emphasize the point that not all communities have equal access to resources (Supplementary Materials: Appendix A-D).

5. VBD outbreak simulation lesson

This lesson was designed for use in college-level classrooms for students learning about One Health, vector-borne diseases, parasitology, or zoonotic diseases. It is an interactive activity adapted from the "building mobiles" activity originally created by Dr. Sandra Lawrence [37]. The lesson objectives include: 1) to acknowledge that there is an inequity in the amount and availability of resources available to combat disease outbreaks across locations, 2) to apply scientific concepts learned in a social context, 3) to identify different entities and their roles in investigating and managing outbreaks, 4) to communicate effectively by collaborating as different entities or experts in combating an outbreak, and 5) to understand the process of securing external grants. Before engaging in this activity, students should have a working understanding of One Health concepts, the disease systems included in the lesson, what entities (e.g., universities, government public health agencies, funding sources) and which individuals are involved in the work of these diseases of public health interest (e.g., doctors, veterinarians, epidemiologists, vector biologists, animal control officers).

5.1. Part 1: activity introduction – engage

Part 1 of the lesson will cover the engage portion of a 5 E science lesson plan model (engage, explore, explain, elaborate, and evaluate) [23,24,38]. The students will receive a short, interactive lecture to introduce the activity and review the previous knowledge they need for the lesson. First, the instructor will *engage* the students by asking them to individually write down a definition of "One Health", and then set this definition aside until the end of the activity. The lecture will also briefly review the different players in solving One Health problems, such as funding agencies, researchers, veterinarians, etc. This section will orient the students to the upcoming activity and give them any background information they may need to participate in the lesson.

5.2. Part 2: planning period - explore

The students will then be divided into groups of 3 to 5 and will sit spread around the room (Fig. 1). Each group will be given identical bags or envelopes encasing their activity materials within (Supplementary Materials: Appendix A-D). Each group will have a unique prompt for a

Fig. 1. Trainees spread around the room during the exploration part of the lesson, working in groups with their specific prompts and budgets to combat their VBD outbreak. Each group has their own color-coded resource cards and prompt (A. has pink, B. has purple, C. has green, and D. has blue) but all have the same color to represent money (A - F all have separate "bills" of money in gold). Funding agencies can fold their prompt in half to remind the room that they are an option to approach after the planning period (F. has the instructor sitting by themselves with the red "CDC" name tent). The regional map should be projected during the exploration to be a visual cue for the trainees (F). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

VBD outbreak, which includes a budget and various experts. The prompt will not explicitly state what the causative agent of the outbreak is, but rather will give details that they could make some hypotheses about what it is. Physical fake money bills that are the same color paper for all groups should be included in each group's materials and correspond to their allocated budgets. Each group will receive other materials in the bag such as scratch paper, pen, and resources cards to manage the outbreak printed on colored paper that is unique to their group. The students will have a 10- to 15-min planning period to manage their budget and create a plan to combat the disease outbreak and propose a hypothesis about what the causative agent may be. This 'planning period' should be brief to incentivize the students to make their plans quickly. Furthermore, the group with the fewest resources may be the first to conclude its plan, which would give it time to observe the other groups. This would represent the fact that the less privileged are the first to notice inequities (Lawrence 1998). Students will *explore* their possibilities in this part depending on the prompt assigned, following the 5 E lesson plan model.

5.3. Part 3: grant application period (optional) - explore

If there is enough time available to perform this part, student groups will have the opportunity to apply for additional funding through various agencies. Examples of agencies include the National Science Foundation (NSF) and the Centers of Disease Control and Prevention (CDC). The goal is to have one agency focused on basic science and another on public health. Funding agencies will be in the room with their own prompts and fictitious resources, represented by students or other instructors, ideally someone who has previously participated in the "mobile" activity (or this activity). The criteria for funding a grant proposal should be clearly written in the prompt of the "funding agencies" to replicate a typical criteria of a proposal to that entity and only visible to the funding agency. By gatekeeping what the funding agency is precisely looking to fund, this mirrors the reality of grant application processes [39,40] but criteria should be applied consistently.

Student groups will need to prepare a proposal or "pitch" for the funding agency and will verbally present their proposal to apply for the grant in front of the class. The funding agency will then award or reject the proposal. This part of the activity will give students the opportunity to practice communicating their scientific reasoning and allow them to form a persuasive argument about why their research should be supported. Additionally, the student observing the presentation can learn how each group manages its outcome and receive feedback. Once all groups have had the opportunity to pitch their proposal, they must pay the grant writing fee. We acknowledge that applying for a grant doesn't necessarily cost money, however it takes resources (e.g., time, salary hours) to write and submit a grant. After the proposals have been presented, the funding agencies should also present their specific prompts to the group explaining what they were looking for. In the final discussion section, the whole group will unpack the inequitable dynamics of applying for funding and getting awarded [39–41].

5.4. Part 4: presentation period – explain and evaluate

At this stage, the students will present their prompts and outbreak management strategy to the group. The group with the highest budget will start first, immediately followed by the group with the lowest budget; the other groups can present in any order. During this period, the instructor can *evaluate* groups by asking what their hypothesis is about the causal agent and how they reached that conclusion. Due to the presentation of their management plan, the group is also *evaluating* each other's plans and can therefore make a hypothesis of the causative agent if the presenting group's answer was unsatisfactory.

5.5. Part 5: group discussion - elaborate

After all the periods have been completed, there will be a reflective group discussion that could be guided by the following questions:

1) What specific thoughts did you have when you received the prompt? What did you observe during the group presentations?
2) What was it like to participate in this activity? Imagine being in one of the other groups, what would it have been like?
3) As many of you will likely follow careers that will deal with outbreaks, how will you take what you have learned from this activity and apply it to a real outbreak scenario?
4) How was the experience of applying for funding like? How did it make you feel?
5) What was the definition of One Health you wrote down at the beginning of the activity? Did that definition apply to the activity or not? How would you change your definition after the activity?

This last part of the activity will be an opportunity to *elaborate* on the resource differences among the groups, the disease and risk associated with each region, and how the two components are related. After discussing the above, students can be encouraged to discuss how they would approach similar issues in real life as future STEM professionals. The lesson can end with the instructor presenting examples from the literature of how systematic racism, classism, sexism, and other systematic oppressive systems have been documented to impact VBD, zoonotic diseases, and other infectious diseases. For that, we recommend the references cited throughout this manuscript. If desired, the instructor can assign the readings along with a reflective writing assignment or a research project to investigate ways these issues can be addressed.

6. Lessons from using the lesson plan

We have implemented this lesson on three occasions in different settings: 1) a research lab meeting, with researchers at different academic levels ranging from undergraduate students to professors, 2) an undergraduate classroom for a Medical Entomology class, and 3) a mixed undergraduate and graduate classroom for a Methods in Vector-Borne Disease class. Based on our experiences as teachers on these occasions, we make the following suggestions for other educators to use this lesson in their own classrooms:

- Approach the activity with an open mind and empathetic viewpoint, students bring different experiences to the classroom and being sensitive to these previous experiences is important.
- Be brief in your instructions before the activity, this will setup the students for the "light bulb" moment when they realize that no instructions were given about how to distribute or share their resources.
- Create a map or a table that highlights the differences in the locations from the activity to share after the activity is complete, providing some data to highlight the differences can help drive home the point that the activity was based on actual data.
- Circulate through the room while the activity is taking place, listen the students' conversations so you can highlight some of your observations during the discussion portion of the lesson.

7. Concluding remarks

This activity combines socioscientific issues, place-based education, and role-playing scenarios in a single framework to expose and discuss societal factors that drive inequities in the fight against vector-borne diseases. Due to a diversity of specific curriculum internationally, this lesson plan has the flexibility for adaptation globally but should only be evaluated within the locality of the activity. By engaging students with diverse backgrounds and career interests, this role-playing lesson plan will aid in the training of future One Health professionals, instructors and policy makers aware that the burden of VDB varies at local (state level), broad (within countries) and global scales.

CRediT authorship contribution statement

Nicole A. Scavo: Writing – original draft, Project administration, Conceptualization. **Sarah Poor:** Writing – review & editing, Conceptualization. **Francisco C. Ferreira:** Writing – review & editing, Conceptualization. **Yuexun Tian:** Writing – review & editing, Conceptualization. **Julia Gonzalez:** Writing – review & editing. **Jordan Salomon:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Funding

For the duration of this work JS was funded by the Texas A&M University Office of Graduate and Professional School Diversity and Dissertation fellowships. NAS and SP were supported by the Texas A&M University Merit Fellowship. FCF was funded by Texas A&M University AgriLife Research. The Ecology & Evolutionary Biology Program at Texas A&M University provided finacial support for publication fees.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to acknowledge that this lesson plan was inspired by the "building mobiles" activity from Dr. Kimberly Tanner and Dr. Jessica Drew from San Francisco State University. Thank you to Dr. Sarah Hamer, Heather Baldi, Dr. Lee Fitzgerald, Dr. Heath Blackmon, and Dr. Gabe Hamer for supporting our endevors with this project. We would like to thank the students and trainees from Texas A&M University in the field methods in vector ecology class, in the Hamer lab group, and in the medical entomology class instructed by Dr. Brandon Lyons for allowing us to practice this lesson and get real-time feedback. We also thank Daniela de Angeli Dutra, Arielle Crews, Cassandra Durden and Xinmi Zhang for the constructive feedback.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2025.101019.

Data availability

No data was used for the research described in the article.

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